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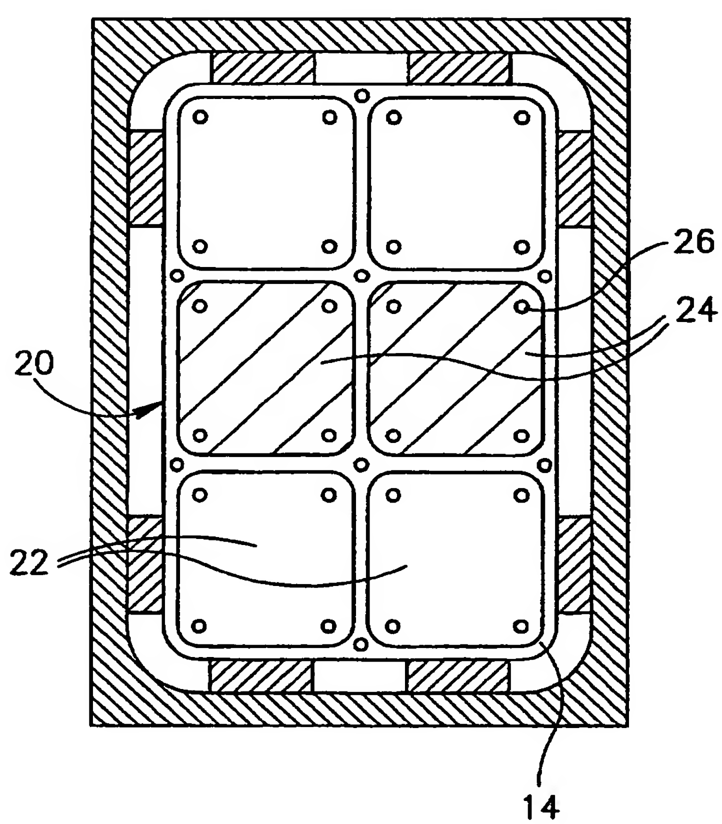

(57) Abstract: A kit for providing an isolating system for a device to be used in a vehicle, comprising: an inner frame (14), adapted to have the device mounted thereon; an outer frame (16) adapted to be mechanically coupled to the vehicle; a plurality of elastomeric elements (18), which interconnect the inner frame to the outer frame, isolating the inner frame from vibrations and shocks encountered by the outer frame; and at least one modular weight (24) adapted to be selectively attached to said inner frame, thereby altering the natural frequency and with it the transmissibility of the isolation system.

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ISOLATING SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to mounting systems that protect against vibration, and in particular to pre-fabricated, integral isolating systems for light-weight devices mounted in vehicles.

BACKGROUND OF THE INVENTION

When a device (for example, a hard disk) is mounted on a vehicle (for example, in a computer of the vehicle), it may require protection from rhythmic and random vibrations and from shocks produced by the moving vehicle. Isolating systems are mounting systems that give protection from vibrations and shocks, by supporting the device with elastomeric elements, i.e., elements made from rubber-type materials. The dynamic characteristics of elastomeric elements, a combination of a spring with an effective spring stiffness, k, in each direction and a damper with an effective coefficient of viscous damping, c, in each direction, can provide this protection. In principle, the spring stores potential energy and its stiffness is analogous to the reciprocal of capacitance in an electrical circuit. The damper dissipates energy and its coefficient is analogous to the resistance in an electrical circuit. The dynamic characteristics are generally determined by the type, composition and geometry of the elastomeric element and by the molding process used to produce it.

In designing isolating systems for a device, one or more of the following is typically considered:

a. Together, a device and its isolating system have several natural frequencies. In general, good protection from vibration and shock is achieved when the first (i.e., lowest) natural frequency is low, for example in the range of 10-20 Hz.

b. The natural frequencies should, typically, be different from any forced frequencies generated by the vehicle, for example, the frequency of a main rotor of a helicopter, in order to avoid resonance. In another example, when the isolating system is designed for a crystal, the natural frequencies should be different from any sensitive frequencies of the crystal. In general, one could refer to frequencies of interest, which should not commensurate with the natural frequency.

c. In general, an isolating system may comprise several elastomeric elements. In known devices, these elements have similar dynamic characteristics. This condition is known as "dynamic matching".

d. Depending on its application, the isolating system may have to withstand harsh environmental conditions, such as high temperatures, high humidity, high levels of dust, sand, or fungus.

Isolating systems are evaluated by a transmissibility distribution, T, which is a ratio between vibrations transmitted to the device (output) and external vibrations (input), which is often shown as a function of different ratios of forced to natural frequencies. When $T > 1$, T is an amplification factor; when $T < 1$ it is an isolating factor.

For a simplified calculation of the transmissibility distribution, T, one may consider a hard disk of a mass m, mounted on an isolating system of effective k and c values in a specific direction (a single degree of freedom.). The hard disk and the isolating system may be inserted in a computer of a vehicle, where the vehicle has a forced frequency ω.

The natural frequency, ρ, of the overall assembly of the hard disk and the isolating system is given by,

1. $\rho = (\text{constant})\,(k/m)^{1/2}$.

We can define a ratio, r, as the frequency ratio,

2. $r \equiv \omega/\rho$.

Furthermore, we can define a parameter, ξ, a damping factor,

3. $\xi \equiv c \,/\, [2(mk)^{1/2}]$.

The transmissibility distribution, T, is a function of both ξ and r. In this simplified, one dimensional model, T is given as,

4. $T = [1 + (2\xi r)^2]^{1/2} \,/\, [(2\xi r)^2 + (1 - r^2)^2]^{1/2}$

(However, generally, a dynamic analysis of an isolating system is carried out by a finite element method, which takes into account multiple degrees of freedom.)

In Fig. 1, the transmissibility distribution, T, is plotted for different values of damping factors ξ and frequency ratios, $r = \omega/\rho$. The transmissibility distribution peaks for each ξ value when a natural frequency coincides with a forced frequency, $\omega/\rho \approx 1$. An approximation of the peak value may be made as,

$$T_{max} \approx 1/(2\xi),$$

In other words, when $\xi = 1/4$, the curve peaks at $T_{max} \approx 2$, and when $\xi = 1/8$, the curve peaks at $T_{max} \approx 4$. In the discussion that follows, the term transmissibility applies to a value read

from the transmissibility curve at an appropriate frequency ratio, while the term peak transmissibility applies to T_{max} at the natural frequency.

The design of an isolating system is based on an evaluation of the forced frequencies of a vehicle and the environmental conditions that must be withstood, together with a value of transmissibility that the isolated device can sustain. Based on these factors, a selection of the type, number and arrangement of elastomeric elements is made.

One approach is to use isolating components, each comprising an elastomeric element attached or bonded to metal. This type of components is provided by companies such as Lord Corp. of Erie, PA USA, or Barry Control Corp. of Burbank, CA USA. In this approach an isolating system is fabricated at a vehicle-fabrication site, made to order for a specific vehicle type, from the isolating components. One disadvantage of this approach is the difficulty in achieving dynamic matching. Components of identical materials, molded at different times, may have different dynamic characteristics. Consequently, a rejection rate of isolating components, due to differences in dynamic characteristics, is high.

In addition, designing an isolating system for each type of vehicle, individually, and fabricating it at a vehicle-fabrication site is not cost effective. Nor does such a process typically benefit from optimum quality control conditions.

Pre-fabricated, integral isolating systems for data storage devices are known. US patents 5,426,562, US patent 5,837,934, US patent 5,770,133, US patent 5,149,048, US patent 5,587,854, US patent 4,937,806 and JP patent 6236669A, the disclosures of which are incorporated herein by reference, are some examples. These patents describe systems of intrinsic natural frequencies. However, applications vary; the forced frequencies encountered on a helicopter are different from those on a tank. It may happen that the natural frequency of an overall assembly is very close to a forced frequency of the vehicle on which the assembly is mounted. Makeshift alterations have to be performed at the vehicle-fabrication site, by changing the stiffness of a structure of the isolating system (if possible) or by replacing the elastomeric elements altogether. Because makeshift alterations may be necessary, the advantages of cost effectiveness and high quality control conditions are somewhat lost.

SUMMARY OF THE INVENTION

An aspect of some exemplary embodiments of the invention relates to providing a configurable pre-fabricated, integral isolating system for a device, for example a lightweight device such as a disk drive. Possibly, the isolating system can be tailored for a range of vehicles, for example by attachable or detachable weights, optionally modular weights. In an

exemplary embodiment of the invention, the system is provided in kit form, for example packaged with operating instructions.

In an exemplary embodiment of the invention, modular weights are added or subtracted in order to achieve a specific natural frequency, and the transmissibility value changes accordingly. Alternatively, modular weights are added or subtracted in order to achieve a specific value of transmissibility, and the natural frequency changes accordingly.

In an exemplary embodiment of the invention, the isolating system is pre-fabricated by a standard manufacturing process, at an isolating system manufacturing site, resulting in one or more of:

a. inherent dynamic matching as all the elastomers are molded at the same time;

b. optimum quality-control conditions; and

c. cost effective production process.

In an exemplary embodiment of the invention, the isolating system is intended for a data-storage device, such as a hard disk which may be installed in a computer or in any other electronic or electro-optic instrument. Alternatively, the isolating system is intended for an electronic device, such as a light-weight computer. Alternatively, the isolating system is intended for an optical device, such as a light-weight camera. Alternatively still, the isolating system is intended for a crystal or a diode. Alternatively still, the isolating system is intended for a component of an electronic instrument or an optical instrument, or an electro-optical instrument.

Optionally, the pre-fabricated, integral isolating system is intended for devices or components in the weight-range between 50 grams and 2000 grams, for example, between 100 and 1000 grams or between 750 and 1500 grams. Alternatively or additionally, the pre-fabricated, integral isolating system is intended for very small devices, or components in the weight range between 1-50 gram. Alternatively, the system may be designed for greater weights.

Various sizes may be provided, for example, matching modular electronic component sizes, both with respect to internal and external dimensions. Standard connector locations (e.g., holes for screws) may also be provided in the pre-fabricated system. Different sizes, materials and/or weights of the isolation system may be provided for different applications.

Optionally, the basic isolating system includes no modular weights, and these may be attached. Alternatively, the basic system includes modular weights and they may be detached, for example, by snipping wires that attach the weights to the system.

Optionally, the pre-fabricated, integral isolating system comprises built-in sockets (recesses) into which modular (or even custom made) weights fit. Alternatively or additionally, the system comprises other docking stations or the weights, for example, bumps and ridges. Alternatively or additionally, the modular weights are flat, and fit on a flat top and (or) bottom and (or) side surfaces of the isolating system. Optionally, they are attached with bolts, latches or clips. Additionally or alternatively, they are attached with an adhesive. The weights may all be the same weight, or a set of weights may be provided.

Optionally, the pre-fabricated, integral isolating system provides isolation-protection in all directions, including three linear axes (x, y and z) and rotation around each of the three axes, however this is not always required and fewer axes may be isolated. Optionally, the dynamic characteristics and/or isolation of the isolating system are substantially the same in the x, y and z. directions. Optionally, protection is substantially the same also in each rotational direction. Alternatively, the pre-fabricated, integral isolating system has different dynamic characteristics in different directions and/or axes, and different levels of protection are achieved for each.

Optionally, the pre-fabricated, integral isolating system may be integrated into the vehicle structure in various attitudes, and be hung from a ceiling, or attached to a single wall, or placed on a floor. Alternatively, the isolating system may be supported at two or more points, comprising, for example, any of the above mounting configurations.

Optionally, a pre-fabricated, integral isolating system applies to a specific make and model of a device, and provides a tight fit for that make and model. Alternatively, an isolating system applies to specific dimensions and may be used for devices that are substantially of those dimensions. Alternatively still, an isolating system may be used for any of several different devices that are relatively close in dimensions, for example, by providing a spring-leaf or another attachment system, such as screws, clips, hooks and/or pressure fittings, for holding the device tightly in place.

Alternatively or additionally, the system is designed for one or more particular external packaging systems and/or sizes, for example a military PC. Alternatively, the system is designed in a range of sizes.

Optionally, the addition or subtraction of modular weights is conducted symmetrically around an x-axis, a y-axis and a z-axis. Alternatively, the addition or subtraction of modular weights is conducted symmetrically around an x-axis and a z-axis, but not around a y-axis.

Optionally, providing an isolating system tailored to a vehicle, comprises providing a plurality of isolating systems tailored to a plurality of vehicles of the same make and model,

such as a plurality of F-15 jets. Alternatively, providing an isolating system tailored to a vehicle, comprises providing an isolating system to a single vehicle or to a few vehicles.

An aspect of some exemplary embodiments of the invention relates to providing a method for tailor-fitting a pre-fabricated isolating system for a device to a specific vehicle, by tuning the natural frequency (and with it, the transmissibility) using modular weights.

In an exemplary embodiment of the invention, tuning is conducted at the manufacturing site and comprises:

a. receiving information about the vehicle's forced frequencies and the mass being isolated;
b. calculating the expected values of the natural frequency, frequency ratio and transmissibility with high accuracy (for example, by using a finite-element method); and
c. adding or subtracting modular weights to the isolated system.

Alternatively, tuning is conducted at the vehicle-fabrication site and comprises:

a. measuring the vehicle's forced frequencies;
b. measuring the natural frequencies of the isolating system with the device installed;
c. calculating the frequency ratio and transmissibility based on the measured values; and
d. adding or subtracting modular weights to the isolating system.

Alternatively or additionally, tuning may be based on a combination of calculated values and measured values.

Optionally, to facilitate calculating expected values of natural frequency, frequency ratio and transmissibility with high accuracy, the isolating system comprises elastomers manufactured as a fully bonded sandwich (metal-rubber-metal, with rubber to metal bonding, optionally by a transfer molding process). Optionally, this manufacturing process provides a tight control over the dynamic properties of the elastomers and close agreement between calculated and measured natural frequencies. Optionally, the close agreement comprises a calculation error no greater than 1.5, 3 or 5 Hz in the natural frequency, or an error of smaller than 10%, 5% or 1%. Alternatively, other manufacturing processes may be used, and tuning the transmissibility is conducted at the vehicle-fabrication site, based on measured frequencies.

There is this provide din accordance with an exemplary embodiment of the invention, a pre-fabricated kit for providing an integral isolating system for a device to be used in a vehicle, comprising:

an inner frame, adapted to have the device mounted thereon;

an outer frame adapted to be mechanically coupled to the vehicle;

a plurality of elastomeric elements, which interconnect the inner frame to the outer frame, isolating the inner frame from vibrations and shocks encountered by the outer frame; and

at least one modular weight element adapted to be selectively attached to said inner frame, thereby altering the natural frequency and with it the transmissibility of the isolation system. Optionally, said weight element is provided attached to said inner frame and is adapted to be removed. Alternatively, said weight element is provided separated from said inner frame and is adapted to be attached to said frame.

In an exemplary embodiment of the invention, said at least one weight element comprises at least two weights. Alternatively or additionally, said at least one weight element comprises at least five weights.

In an exemplary embodiment of the invention, said weight elements are all the same in size and weight. Alternatively, said weight elements have at least two different weights. Alternatively or additionally, said weight elements have at least two different shapes.

In an exemplary embodiment of the invention, said at least one weight element has a rectangular shape. Alternatively, said at least one weight element has a flat cylindrical shape.

In an exemplary embodiment of the invention, said inner frame includes at least one docking station for mounting said at least one weight element therein. Optionally, said docking station comprise a plurality of sockets. Alternatively or additionally, said at least one docking station is arranged to allow a center of gravity of said system, in at least one axis, to be maintained when said at least one weight element is attached.

In an exemplary embodiment of the invention, said outer frame is adapted to attach to said vehicle. Alternatively or additionally, said outer frame is manufactured to match at least one a standardized packing size. Alternatively or additionally, said inner frame is manufactured to match at least one a standardized component size. Alternatively or additionally, said elastomeric elements are arranged in a plane. Alternatively, said elastomeric elements are placed on six sides of said inner frame.

In an exemplary embodiment of the invention, all of said elastomeric elements are the same. Alternatively, at least two of said elastomeric elements are different.

In an exemplary embodiment of the invention, the elastomeric elements are dynamically matched. Alternatively or additionally, each elastomeric element is a fully bonded metal-rubber-metal sandwich by a transfer molding process. Alternatively or additionally, the elastomeric elements provide isolation in x, y and z axes and in three corresponding rotational axes. Alternatively or additionally, the elastomeric elements have

substantially similar dynamic characteristics in the x, y, and z directions. Alternatively or additionally, the kit is adapted to be integrated into a vehicle in any attitude. Alternatively or additionally, said device is removable from said system. Alternatively or additionally, said system is sealed to be air-tight. Alternatively or additionally, said system is sealed to be water-tight. Alternatively or additionally, said vehicle is an airborne vehicle. Alternatively or additionally, said vehicle is a ground vehicle. Alternatively or additionally, said vehicle is a water borne vehicle. Alternatively or additionally, said device is isolated from large amplitude sinusoidal vibrations. Alternatively or additionally, said device is isolated from large amplitude shock vibrations. Alternatively or additionally, said device is isolated from large amplitude random vibrations. Alternatively or additionally, said device is isolated from motor vibrations. Alternatively or additionally, said at least one weight element is selected to have a combined weight greater than 50% of the weight of the inner frame and the device. Alternatively or additionally, said at least one weight element is selected to have a combined weight greater than 100% of the weight of the inner frame and the device. Alternatively or additionally, said at least one weight element is selected to have a combined weight greater than 400% of the weight of the inner frame and the device. Alternatively or additionally, said at least one weight element is selected to have a combined weight greater than 800% of the weight of the inner frame and the device.

In an exemplary embodiment of the invention, the kit is integrated with a mechanical memory device or an electro-optronic device.

There is also provided in accordance with an exemplary embodiment of the invention, a method of manufacturing a kit for an isolation system, comprising:

providing an inner frame, including at least one docking station for a weight;

providing an outer frame; and

transfer molding at least one elastomeric element between said inner and said outer frames.

There is also provided in accordance with an exemplary embodiment of the invention, a method of tuning a modular isolation system, comprising:

selecting a modular isolation system kit for a vehicle and a device;

determining a natural frequency or transmissibility for the isolation system and the device;

determining a modular weight to be added or removed to said isolation system; and

adding or removing said weight element, to achieve a desired isolation behavior. Optionally, said weight element is attached to said system. Alternatively, said weight element

is removed from said system.

In an exemplary embodiment of the invention, the method comprises:

determining a sensitive frequency of said device; and

determining said desired isolation behavior based on said sensitive frequency. Alternatively or additionally, selecting a modular isolation system kit comprises selecting from a range of available kits. Alternatively or additionally, selecting a modular weight element comprises maintaining a center of gravity of said system. Alternatively or additionally, selecting a modular weight element comprises avoiding a sensitive frequency of said device. Alternatively or additionally, said weight element has a weight of at least 50% of a weight of said inner frame and said device. Alternatively or additionally, said weight element has a weight of at least 200% of a weight of said inner frame and said device. Alternatively or additionally, said weight element has a weight of at least 800% of a weight of said inner frame and said device.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting exemplary embodiments of the present invention will be now be described in the following detailed description of exemplary embodiments of the invention, with reference to the attached drawings, in which same or similar number designations are maintained throughout the figures for each element and in which:

Fig. 1 illustrates transmissibility curves for different values of damping factors and frequency ratios;

Figs. 2A and 2B schematically illustrate a pre-fabricated, integral isolating system comprising modular weights and sockets for them, in accordance with an exemplary embodiment of the invention;

Figs. 3A and 3B schematically illustrate different modular-weight arrangements, in accordance with some exemplary embodiments of the invention;

Figs. 4 schematically illustrates a constant "center-of-gravity" condition that is maintained with the additions of weights, in accordance with an exemplary embodiment of the invention;

Fig. 5 illustrates a relationship of transmissibility T as a function of mass for different initial damping factors, ξ, assuming an initial mass of 500 gram, and resonance at 20 Hz; and

Figs. 6A and 6B illustrate, in a flow-chart format, the method of providing a specific vehicle type with a pre-fabricated, integral isolating system that is tailored to it.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Reference is now made to Figs. 2A and 2B which schematically illustrate a top view

and a bottom view, respectively of an exemplary pre-fabricated, integral isolating system 10, that includes a plurality of elastomeric elements 18, one or more modular weights 24 in one or more sockets 22, and containing a hard disk 12, in accordance with an exemplary embodiment of the invention. Together, isolating system 10 and hard disk 12 constitute an overall assembly 21 having a known set of natural frequencies and a known first (lowest) natural frequency.

Other types of data storage device may be provided instead of disk 12, for example, a CD player and a diskette drive. Alternatively, other electronic, optical, electro-mechanical or electro-optical devices are provided, for example, a diskette drive.

In an exemplary embodiment of the invention, overall assembly 21 may be mounted on any one of a plurality of different types of vehicles (for example, a Boeing 747, not shown) wherein the vehicle may have a specific set of forced frequencies at a range close to the first natural frequency of overall assembly 21 and/or close to a sensitive frequency of disk 12 (or any other isolated device). Resonance and high transmissibility encountered when a natural frequency and a forced frequency commensurate, can be avoided, for example, by adding modular weights 24 to assembly 21 in a specific number and/or arrangement, determined for the specific type of vehicle, thus altering the natural frequencies of overall assembly 21 and the transmissibility of isolating system 12.

Exemplary vehicles include, cars, motorcycles, humans (e.g., for hand carried devices), trains, airplanes (civilian, military, jet and propeller), helicopters, hovercraft, ships, boats, undersea vehicles, space ships and rockets. In some cases, the "vehicle" does not move, for example, when the isolated device is mounted in a control room of a factory or a mine.

Optionally, isolating system 10 is pre-fabricated by a standard manufacturing process, at an isolating system manufacturing site, resulting in inherent dynamic matching as all of elastomeric elements 18 are molded at in one molding process, optimum quality-control conditions, and cost effective production process. Alternatively, mismatching maybe compensated for, for example, by adding and removing of weights and/or moving the center of gravity.

Optionally, each of elastomeric element 18 is a fully bonded, metal-rubber-metal sandwich, with rubber to metal bonding by a transfer molding process.

Optionally, the forced frequencies for the vehicle, for a specific location within the vehicle (for example, in the cockpit, not shown) are determined at a vehicle-fabrication site (not shown), and a specific arrangement of modular weights 24 is selected for the type of vehicle and for the location within it. Optionally, modular weights 24 are installed at the isolating system manufacturing site, under optimum quality-control conditions, to insure a

tight control of the natural frequency of overall assembly 21. The tailored assembly 21 is then shipped to the vehicle-fabrication site.

As shown in the exemplary embodiment of Figs. 2A and 2B, isolating system 10 comprises an outer frame 16 and an inner frame 14, both made, for example of metal and/or plastic. Optionally, outer frame 16 is of proper dimensions to be inserted in a hard-disk slot (not shown) for example in a computer (not shown) provided in the vehicle. Alternatively or additionally, the geometry and/or connector locations of outer frame 16 may match other standardized receptacles known in the art.

In an exemplary embodiment of the invention, inner frame 14 is smaller (in all dimensions) than outer frame 16. Optionally, inner frame 14 is of proper dimension to provide a tight fit with hard disk 12. Possibly, frame 14 is made to match one or more standardized sizes for devices, such as hard disks. Alternatively, one or more spring-leaf arrangements, or other arrangements hold hard disk 12 tightly inside inner frame 14. Similarly, one or more spring-leaf arrangements, and/or other arrangements, such as screws or adhesive maintain outer frame 16 fixed in its slot.

In an exemplary embodiment of the invention, elastomeric elements 18, distributed, for example, along the four sides of hard disk 12, in a gap 19 between the two metal frames, provide the desired stiffness and damping of the system. Optionally, gap 19 between the two metal frames is of the order of 8 mm. Alternatively, gap 19 has a value between 1 mm and 50 mm. Optionally, there are eight elastomeric elements, two on each side of hard disk 12. Alternatively, another arrangement and another number of elastomeric elements may be used. Optionally, elastomeric elements 18 are arranged in a symmetric manner around inner frame 14. In an exemplary embodiment of the invention, each of elements 18 comprise a pair of staggered "C" or "W" shaped elastomeric elements, in which the two arms of the shape are attached to the inner and outer frames (described below), respectively. Alternatively, a single element 18 may be provided, for example, a band like element surrounding inner frame 14.

Elastomeric elements may also be provided above or below disk 12. Other arrangements may be used for devices or receptacles that are not box-like.

In an exemplary embodiment of the invention, inner frame 14 and/or outer frame 16 are designed to allow easy field removal or replacement of disk 12. In an exemplary embodiment of the invention, inner frame 14 can be opened at one end, and the disk slid out. Alternatively or additionally, outer frame 16 includes two parts, an external body and an internal part to which elements 18 are attached. In one embodiment, for example, the internal part may slide out.

In an exemplary embodiment of the invention, frame 14 and/or frame 16 are air and/or water tight. Such tightness assists in qualifying a device for high altitudes and for various temperature extremes. Different degrees of sealing may be provided for different anticipated operating conditions. Optionally, system 21 includes a desiccant package, to reduce internal humidity. Alternatively or additionally, a pressure equalization valve may be provided, to prevent internal pressures that are two high and/or too low.

Fig. 2A illustrates a top surface 20 of inner frame 14 comprising weight sockets 22, distributed along it. Modular weights 24 are shown inserted in the two middle sockets. Optionally, modular weights 24 are mechanically attached to sockets 22 with bolts 26. Bolts 26 may be, for example, corner bolts, as shown, or center bolts. Alternatively or additionally, modular weights 24 are glued to top surface 20 with an adhesive. Alternatively, modular weights 24 are mechanically attached to top surface 20 in any other known manner that insures strong hold under vibration and shock. In other devices, sockets 22 may be on the sides and/or bottom of frame 14 or at angles thereto, alternatively or additionally to being on top 20.

Reference is now made to Figs. 3A and 3B, which illustrate two additional exemplary arrangements of sockets for weights 24 on top surface 20 of inner frame 14, in accordance with some other exemplary embodiments of the invention. Fig. 3A illustrates a modular weight arrangement that includes modular fractions of weights, such as socket for a half weight 23. Fig. 3B illustrates a modular weight arrangement of concentric rings, such as weights 25 and 27. These different weights may have same or different weights. It should be noted that the socket arrangement need not be rotationally and/or mirror symmetric, in any axis.

In an exemplary embodiment of the invention, the isolation system is provided pre-packaged with a set of weights and an instruction sheet, associating weight combination and/or arrangements with particular isolated devices and/or vehicles. In an exemplary embodiment of the invention, this allows a single device that includes an isolated component to be easily ported between different vehicles. Alternatively or additionally, this simplifies the work of a system integrator, faced with a plurality of possible devices, vehicles and/or components, in a single manufacturing line.

Reference is now made to Fig. 4, which illustrates a pre-fabricated, integral isolating system 34 to which modular weights have been added in a manner that maintains it as a "center-of-gravity" system, in accordance with an exemplary embodiment of the invention. In a "center-of-gravity" system, the center of gravity of the system coincides with an elastic

center around which vibration takes place. In isolating system 34, modular weights 24 have been added both to top surface 20 and to a bottom surface 36, in a symmetric manner. In some cases, the arrangement complements an asymmetry of the isolated device. For isolating system 34, a point 32 is both the center of gravity and the elastic center, both before and after the addition of modular weights. Optionally, different weight designs may be added to top surface 20 and to bottom surface 36, while the weight addition to top surface 20 and to bottom surface 36 is substantially the same. The center of gravity may be maintained, for example, in one, two or three axes.

Fig. 4 also illustrates a side cross-sectional view of pre-fabricated, integral isolating system 34 which comprises elastomeric-elements 18 and additional elastomeric elements 38, in accordance with an exemplary embodiment of the invention. Elastomeric elements 38 are optionally provided to top surface 20 and (or) to a bottom surface 36. Optionally, their purpose is to protect hard disk 12 from a deflection resulting from static or dynamic forces, and especially from high deflection that may be incurred during a shock. Optionally, the elastomeric-element geometry shown in Fig. 4 is designed to achieve a very low natural frequency for overall assembly 21. Optionally, elastomeric elements 18 are designed as buckling-column elements, and elastomeric elements 38 are designed as domes, or cylinders. Alternatively, other geometric shapes may be used. In some exemplary embodiments of the invention, the isolating system, such as isolating system 10, comprises only elastomeric elements 18.

It should be noted that in some applications, maintaining a center of gravity of the isolated system may not be essential. In other applications, maintaining a center of gravity may be desirable.

Reference is now made to Fig. 5 which illustrates a transmissibility distribution, T, as a function of mass change for different damping factors, based on equations 1-4 and assuming an initial mass m = 500 gram, and initially, resonance at $\omega = \rho = 20$ Hz. (with additions or subtractions of mass, there is no longer resonance.) Fig. 5 illustrates that when the damping factor is relatively low, transmissibility is very sensitive to weight changes. But when the damping factor is relatively high, transmissibility is far less sensitive to weight changes., as follows:

a. damping factor is relatively low (initially $\xi = 0.0625$), a 56% change in mass will bring the transmissibility down from $T_{max} = 8.06$ (at resonance) to $T = 1.75$ (at the same frequency of interest, although the natural frequency has shifted), a 78% reduction;

b. damping factor is intermediate (initially $\xi = 0.125$) a 56% change in mass will bring the transmissibility down from $T_{max} = 4.12$ (at resonance) to $T = 1.68$ (at the same frequency of interest, although the natural frequency has shifted), a 59% reduction; and

c. damping factor is relatively high (initially $\xi = 0.250$) a 56% change in mass will bring the transmissibility down from $T_{max} = 2.24$ (at resonance) to $T = 1.49$ (at the same frequency of interest, although the natural frequency has shifted), a 33% reduction.

Fig. 5 also illustrates an interesting feature of equation (4), that whenever resonant conditions occur, doubling the system mass will bring the transmissibility from any peak value of T_{max} to the value, $T = 1.75$ (at the same frequency of interest, although the natural frequency has shifted), regardless of the initial conditions. Even an undamped system can be thus controlled by doubling its weight. In some embodiments of the invention, modular weights (for increasing device weight) are used instead of better damping.

Reference is now made to Figs. 6A and 6B which summarize with a flow chart 100 a process of tailor-fitting an isolating system to a specific vehicle type, by tuning the natural frequency (and with it the transmissibility) to desirable values with modular weights, in accordance with an exemplary embodiment of the invention, as follows:

a. At 102, a request for a pre-made or pre-fabricated integral isolating system for a specific type of a light-weight device, a specific type of vehicle, specific environmental conditions and an allowable transmissibility value is received;

b. At 104, forced frequencies of the vehicle near or at the location that the isolating system will be installed are provided. Measurements at the vehicle-fabrication site may be performed when the information is not available;

c. At 106, the most appropriate pre-fabricated, integral isolating system is selected based on the type of the device, the range of forced frequencies, and the environmental conditions that may be incurred;

d. At 108, the natural frequency and the transmissibility values of the assembly of isolating system and device are calculated with high-accuracy, optionally using a finite-element method, at the isolating system manufacturing site;

e. At 110, an evaluation is made: Is the addition of modular weights necessary to achieve the desired isolation?

f. At 112, when the answer to 110 is "yes", modular weights are attached to the isolating system, at the isolating system manufacturing site; and

g. At 114, pre-fabricated, integral isolating systems that are tailored to the specific type of vehicle are provided.

h. Alternatively, at 116, when the answer to 110 is "no", off-the- self isolating systems are provided.

In some exemplary embodiments of the invention, the isolating system comprises any one or a combination of any of the following:

a. Elastomeric elements manufactured as a fully bonded sandwich (metal-rubber-metal, with rubber to metal bonding, optionally by a "transfer molding" process).

b. Elastomeric-elements that are resilient and return to an initial position after being exposed to external loading.

c. Elastomeric-elements that are designed to withstand various loads in tension, compression, shear and buckling.

d. Elastomeric-elements that are designed to withstand sinusoidal vibrations as well as random vibrations (for example, for an aircraft with a turbo-propeller engine.) and shocks (for example, upon an aircraft landing).

e. Elastomeric-elements that are designed to withstand a static load (for example, a self-weight of parts of the isolating system and/or of disk 12, under normal gravity and/or due to acceleration, for example, upon an aircraft making a high-speed turn).

f. Elastomeric-elements that have a service life longer than the expected usable life of the device.

In some exemplary embodiments of the invention, the isolating system is specifically designed for optimum performance in any one of the following:

a. a forced frequency range of 10-20 Hz;

b. a forced frequency range of 20-30 Hz; or

c. a forced frequency range of 30-50 Hz.

However, the invention is not limited to the range of forced frequencies described here, and optimum performance may be designed for another range of forced frequencies.

In some exemplary embodiments of the invention, the isolating system comprises elastomers of specific materials, in order to withstand specific environmental conditions. The specific elastomeric materials may be, for example, any one of the following:

a. natural rubber, for example, for high strength, excellent fatigue properties, low to medium damping properties and a temperature range higher than -18^{0}C but lower than 80^{0}C;

b. Neoprene, for example, for high strength, good fatigue properties, low to medium damping properties, oil resistance and a temperature range higher than -18°C but lower than 80°C;

c. Lord SPE®-1 of Lord Corp., Erie, PA USA, for example, for high strength, good fatigue properties, low to medium damping and good flexibility to temperatures as low as -55°C;

d. silicon-based elastomers that meet primary US military specifications such as MIL-STD-810, for example, silicon-based elastomers of Barry Control Corp., of Burbank, CA USA, or silicon-based elastomers of Lord BTR™ or BTR™ II of Lord Corp., Erie, PA USA;

e. silicon-based elastomers such as Lord® MED, or MEE of Lord Corp., Erie, PA USA, for example, for medium or low damping and high consistency over a wide range of temperatures down to -57°C.

However, the invention is not limited to the types of elastomers described here, and other types of elastomeric elements may be used instead.

In some exemplary embodiments of the invention, the modular weights have equal weights. Alternatively, the modular weights have unequal weights, for example designed with incremental steps that result in equal natural frequency step changes. For example, for 500-gram assembly 21, a modular weight addition of 117 g will reduce the natural frequency from 20 Hz to 18 Hz, a second modular weight addition of 164 g will reduce the natural frequency further to 16 Hz.

In some exemplary embodiments of the invention, the system is designed so that the modular weights together represent between 50% and 300% of the initial weight of assembly 21 and/or the weight of disk 12. Alternatively, the modular weights are designed so that together they represent between 300% and 800% of the initial weight of assembly 21. Alternatively still, the modular weights are designed so that together (when all the sockets are full) they represent between 800% and 1200% of the initial weight of assembly 21. Optionally, a system of modular weights includes between 2 and 20 modules. Alternatively, only one modular weight (which may be a concentric ring), or a number of weights greater than 20 may be used. However, the invention is not limited to the range of weight and to the number of modular weights described here, and another range of weight percent and another number of weights may be used.

In some exemplary embodiments of the invention, the same modular weight designs may be used for different pre-fabricated, integral isolating systems, for example, for pre-fabricated, integral isolating systems manufactured with different elastomeric material, or a different overall design, or for different environmental conditions, or for a different forced frequency range. In some exemplary embodiments of the invention, modular weights of the same shape and size, but of different weights are provided, from different materials, for different applications.

In some exemplary embodiments of the invention, isolating system 10 or isolating system 34 are designed in a manner that allows overall assembly 21 to be detached from its slot in the vehicle, and be reinserted.

In an exemplary embodiment of the invention, a pre-fabricated isolation system is used for convenient supply of qualified embedded devices, for example, for the aerospace industry. Typically, when designing an aerospace device, the isolation and qualification stages, for a particular component, are quite long, so the manufacturer purchases a large number of components. However, once the purchased components are used up, it may not be possible to obtain new components, for example, due to changes in manufacturing lines at the component manufacturers.

In an exemplary embodiment of the invention, the use of a pre-fabricated modular isolation system, allows a qualification process to be completed in a shorter time, thus allowing off-the-shelf components to be used, and, once the components are no longer available, to qualify new components. In an exemplary embodiment of the invention, a qualification service provider provides isolated and qualified components to system manufacturers, by purchasing off-the-self components and qualifying them, using an isolation system, for example as described above. The isolation systems may be purchased from an isolation system manufacturer.

The present invention has been described using non-limiting detailed descriptions of exemplary embodiments thereof that are provided by way of example and are not intended to limit the scope of the invention. Details shown with respect to one embodiment of the invention, may be used with other embodiments, if suitable for such embodiments. Further, some details of some embodiments are non-essential. Furthermore, while some features of the embodiments are described in terms of particular examples thereof, it should be understood that these features are mere examples of broader classes of features which may be employed. Variations of embodiments described and combinations thereof will occur to persons of the art. Furthermore, the terms "comprising," "comprise," include," and "including" or the like,

shall mean, when used in the claims, "including but not necessarily limited to." The scope of the invention is limited only by the following claims:

CLAIMS

1. A pre-fabricated kit for providing an integral isolating system for a device to be used in a vehicle, comprising:

an inner frame, adapted to have the device mounted thereon;

an outer frame adapted to be mechanically coupled to the vehicle;

a plurality of elastomeric elements, which interconnect the inner frame to the outer frame, isolating the inner frame from vibrations and shocks encountered by the outer frame; and

at least one modular weight element adapted to be selectively attached to said inner frame, thereby altering the natural frequency and with it the transmissibility of the isolation system.

2. A kit according to claim 1, wherein said weight element is provided attached to said inner frame and is adapted to be removed.

3. A kit according to claim 1, wherein said weight element is provided separated from said inner frame and is adapted to be attached to said frame.

4. A kit according to any of claims 1-3, wherein said at least one weight element comprises at least two weights.

5. A kit according to any of claims 1-3, wherein said at least one weight element comprises at least five weights.

6. A kit according to claim 4 or claim 5, wherein said weight elements are all the same in size and weight.

7. A kit according to claim 4 or claim 5, wherein said weight elements have at least two different weights.

8. A kit according to claim 4 or claim 5, wherein said weight elements have at least two different shapes.

9. A kit according to any of claims 1-8, wherein said at least one weight element has a rectangular shape.

10. A kit according to any of claims 1-8, wherein said at least one weight element has a flat cylindrical shape.

11. A kit according to any of claims 1-10, wherein said inner frame includes at least one docking station for mounting said at least one weight element therein.

12. A kit according to claim 11, wherein said docking station comprise a plurality of sockets.

13. A kit according to claim 11 or claim 12, wherein said at least one docking station is arranged to allow a center of gravity of said system, in at least one axis, to be maintained when said at least one weight element is attached.

14. A kit according to any of claims 1-13, wherein said outer frame is adapted to attach to said vehicle.

15. A kit according to any of claims 1-14, wherein said outer frame is manufactured to match at least one a standardized packing size.

16. A kit according to any of claims 1-15, wherein said inner frame is manufactured to match at least one a standardized component size.

17. A kit according to any of claims 1-16, wherein said elastomeric elements are arranged in a plane.

18. A kit according to any of claims 1-16, wherein said elastomeric elements are placed on six sides of said inner frame.

19. A kit according to any of claims 1-18, wherein all of said elastomeric elements are the same.

20. A kit according to any of claims 1-18, wherein at least two of said elastomeric elements are different.

21. A kit according to any of claims 1-20, wherein the elastomeric elements are dynamically matched.

22. A kit according to any of claim 1-21, wherein each elastomeric element is a fully bonded metal-rubber-metal sandwich by a transfer molding process.

23. A kit according to any of claims 1-22, wherein the elastomeric elements provide isolation in x, y and z axes and in three corresponding rotational axes.

24. A kit according to any of claims 1-23, wherein the elastomeric elements have substantially similar dynamic characteristics in the x, y, and z directions.

25. A kit according to any of claims 1-24, wherein the kit is adapted to be integrated into a vehicle in any attitude.

26. A kit according to any of claims 1-25, wherein said device is removable from said system.

27. A kit according to any of claims 1-26, wherein said system is sealed to be air-tight.

28. A kit according to any of claims 1-26, wherein said system is sealed to be water-tight.

29. A kit according to any of claims 1-28, wherein said vehicle is an airborne vehicle.

30. A kit according to any of claims 1-28, wherein said vehicle is a ground vehicle.

31. A kit according to any of claims 1-28, wherein said vehicle is a water borne vehicle.

32. A kit according to any of claims 1-31, wherein said device is isolated from large amplitude sinusoidal vibrations.

33. A kit according to any of claims 1-32, wherein said device is isolated from large amplitude shock vibrations.

34. A kit according to any of claims 1-33, wherein said device is isolated from large amplitude random vibrations.

35. A kit according to any of claims 1-34, wherein said device is isolated from motor vibrations.

36. A kit according to any of claims 1-35, wherein said at least one weight element is selected to have a combined weight greater than 50% of the weight of the inner frame and the device.

37. A kit according to any of claims 1-35, wherein said at least one weight element is selected to have a combined weight greater than 100% of the weight of the inner frame and the device.

38. A kit according to any of claims 1-35, wherein said at least one weight element is selected to have a combined weight greater than 400% of the weight of the inner frame and the device.

39. A kit according to any of claims 1-35, wherein said at least one weight element is selected to have a combined weight greater than 800% of the weight of the inner frame and the device.

40. A kit according to any of claims 1-39, having an electro-mechanical memory device mounted as said device.

41. A kit according to any of claims 1-39, having an electro-optronic device mounted as said device.

42. A method of manufacturing a kit for an isolation system, comprising:
providing an inner frame, including at least one docking station for a weight;
providing an outer frame; and

transfer molding at least one elastomeric element between said inner and said outer frames.

43. A method of tuning a modular isolation system, comprising:

selecting a modular isolation system kit for a vehicle and a device;

determining a natural frequency or transmissibility for the isolation system and the device;

determining a modular weight to be added or removed to said isolation system; and

adding or removing said weight element, to achieve a desired isolation behavior.

44. A method according to claim 43, wherein said weight element is attached to said system.

45. A method according to claim 43, wherein said weight element is removed from said system.

46. A method according to any of claims 43-45, comprising:

determining a sensitive frequency of said device; and

determining said desired isolation behavior based on said sensitive frequency.

47. A method according to any of claims 43-46, wherein selecting a modular isolation system kit comprises selecting from a range of available kits.

48. A method according to any of claims 43-47, wherein selecting a modular weight element comprises maintaining a center of gravity of said system.

49. A method according to any of claims 43-48, wherein selecting a modular weight element comprises avoiding a sensitive frequency of said device.

50. A method according to any of claims 43-49, wherein said weight element has a weight of at least 50% of a weight of said inner frame and said device.

51. A method according to any of claims 43-50, wherein said weight element has a weight of at least 200% of a weight of said inner frame and said device.

52. A method according to any of claims 43-50, wherein said weight element has a weight of at least 800% of a weight of said inner frame and said device.

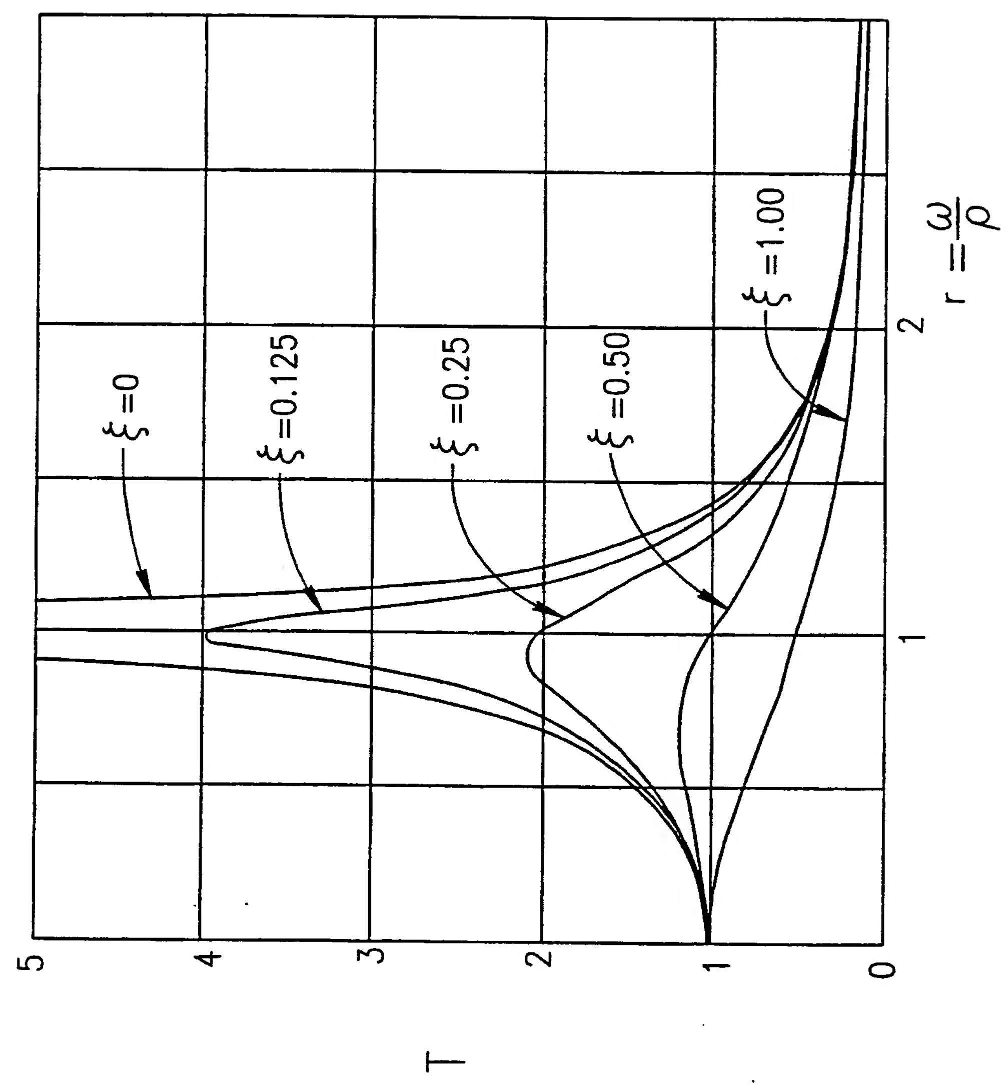


FIG.1

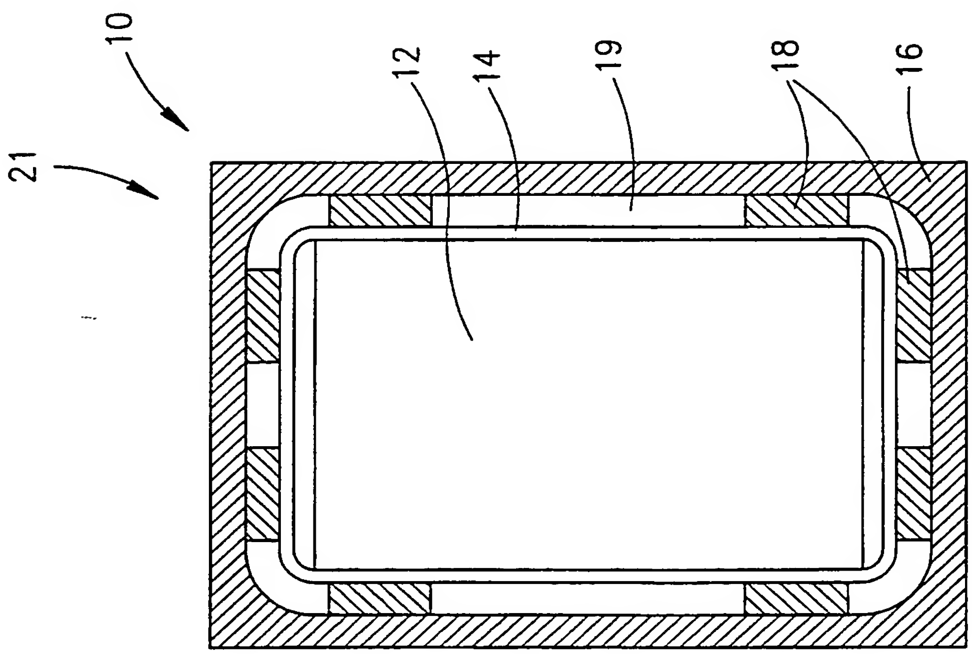


FIG.2B

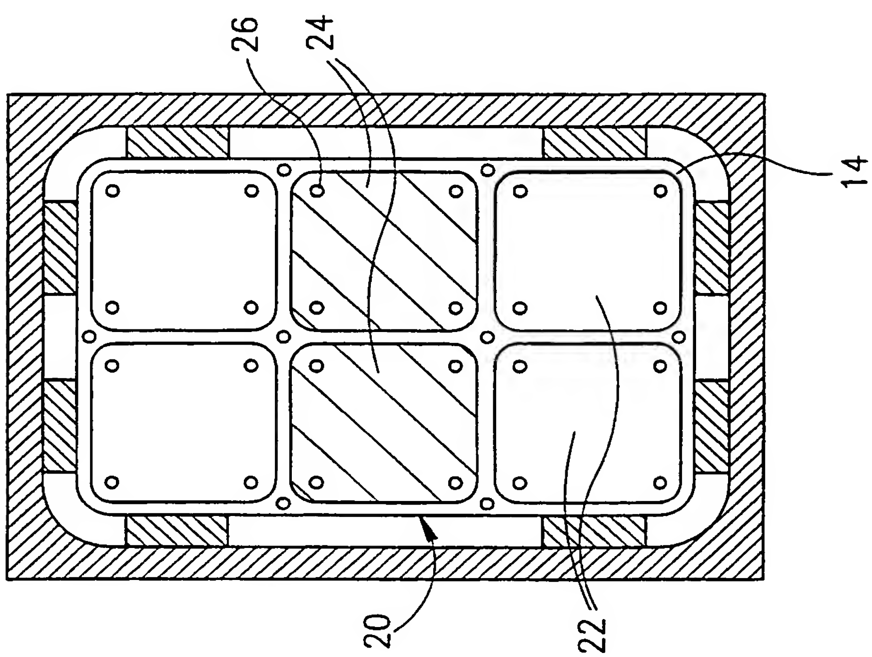


FIG.2A

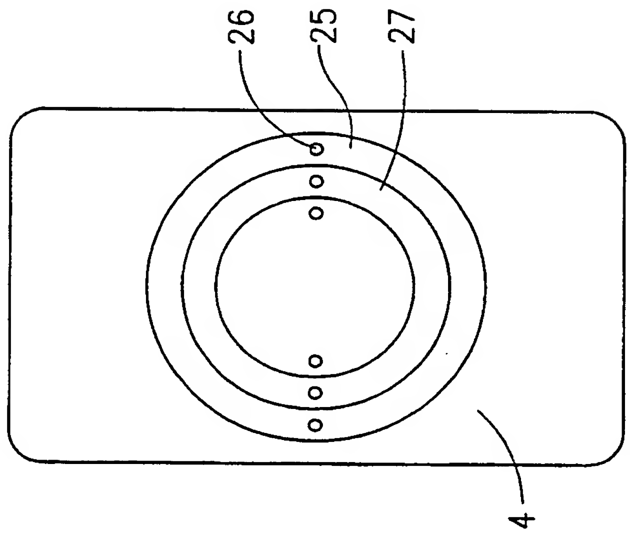


FIG.3B

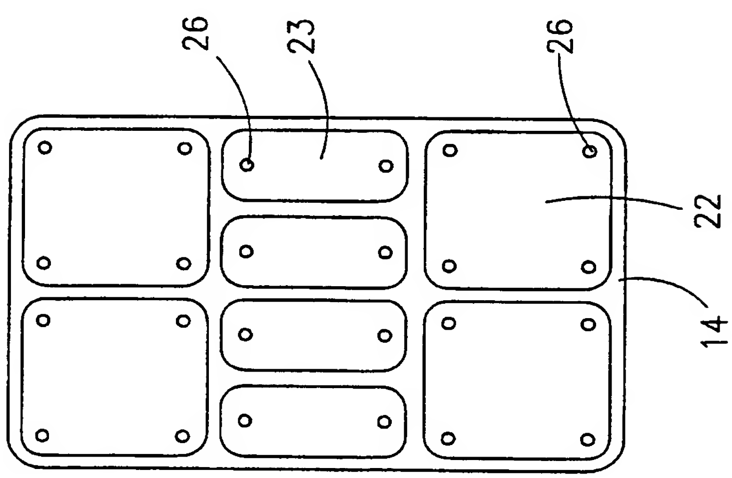


FIG.3A

4/7

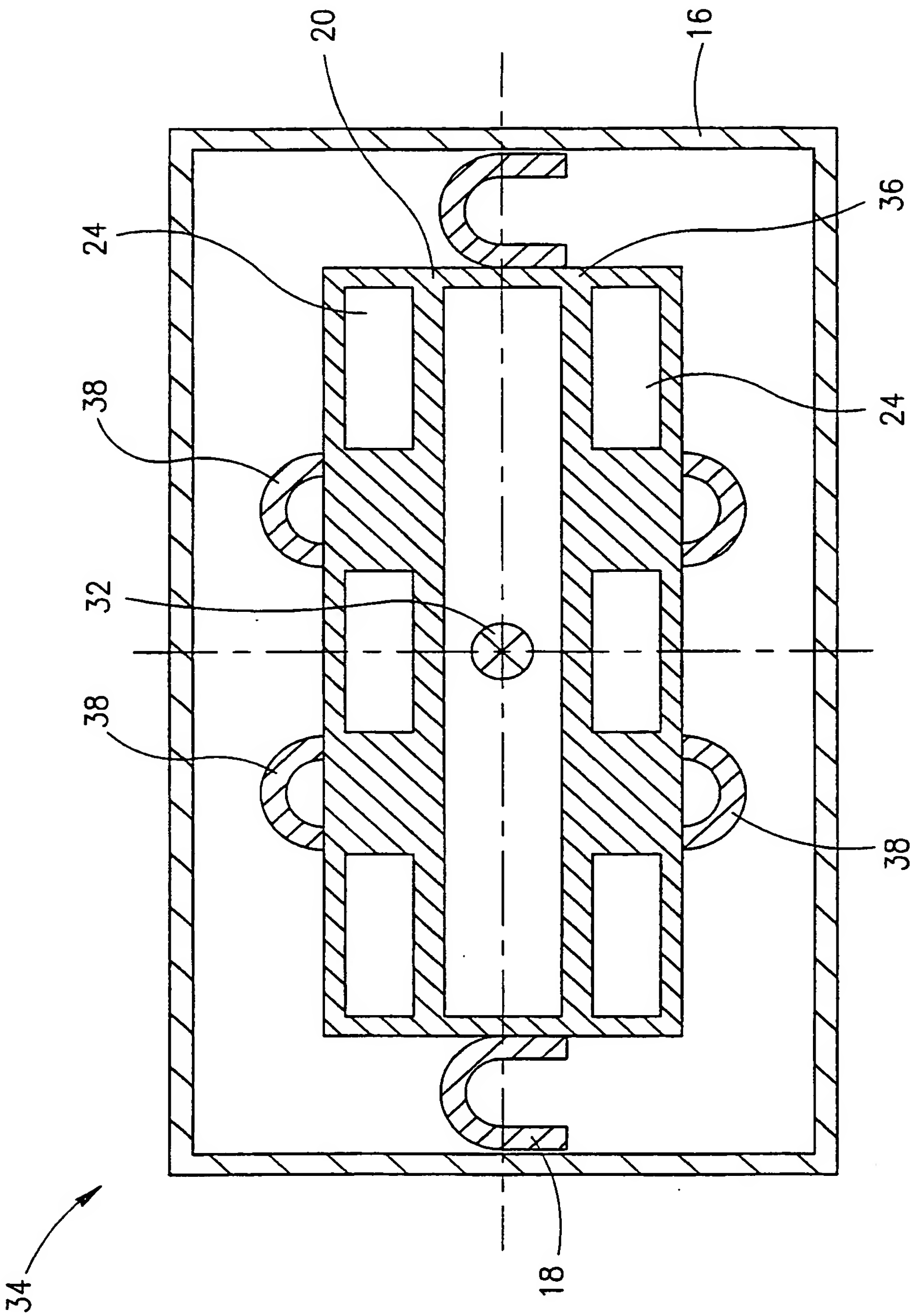
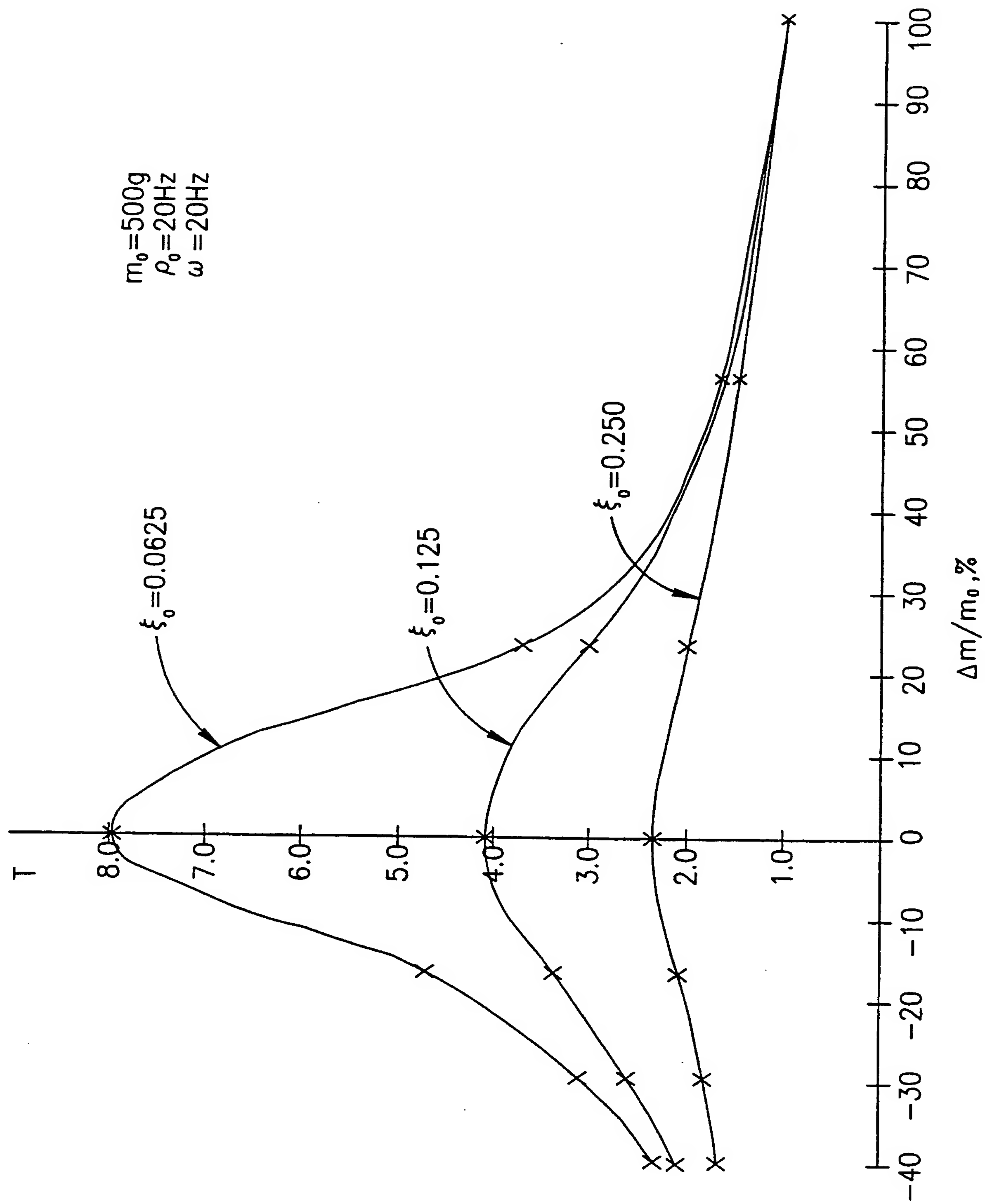


FIG.4



m_0=500g
ρ_0=20Hz
ω =20Hz
ξ_0=0.0625
ξ_0=0.125
ξ_0=0.250
T
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
-40
-30
-20
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10
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80
90
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$\Delta m/m_0$,%

FIG.5

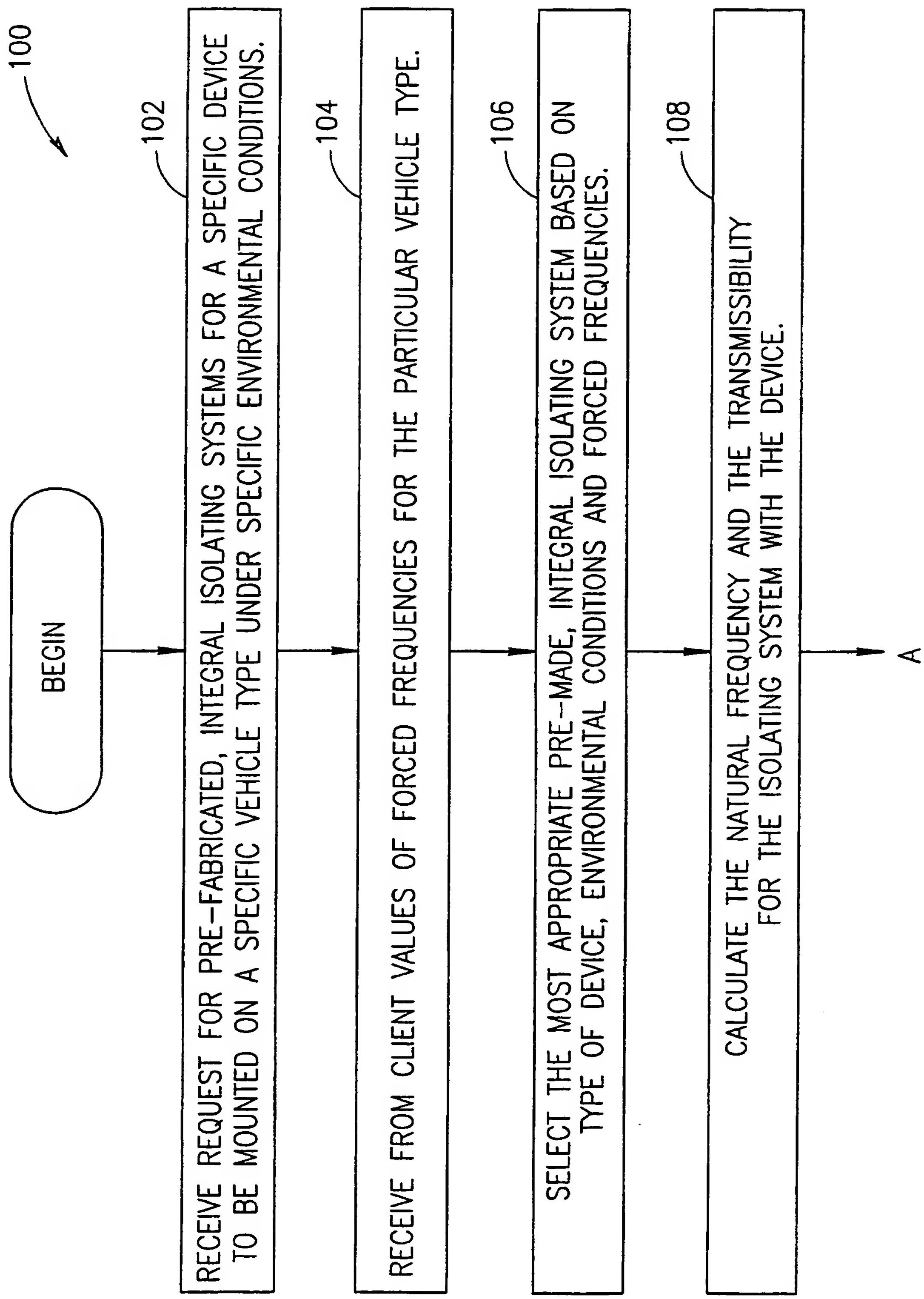
100
BEGIN
102
RECEIVE REQUEST FOR PRE-FABRICATED, INTEGRAL ISOLATING SYSTEMS FOR A SPECIFIC DEVICE TO BE MOUNTED ON A SPECIFIC VEHICLE TYPE UNDER SPECIFIC ENVIRONMENTAL CONDITIONS.
104
RECEIVE FROM CLIENT VALUES OF FORCED FREQUENCIES FOR THE PARTICULAR VEHICLE TYPE.
106
SELECT THE MOST APPROPRIATE PRE-MADE, INTEGRAL ISOLATING SYSTEM BASED ON TYPE OF DEVICE, ENVIRONMENTAL CONDITIONS AND FORCED FREQUENCIES.
108
CALCULATE THE NATURAL FREQUENCY AND THE TRANSMISSIBILITY FOR THE ISOLATING SYSTEM WITH THE DEVICE.
A

FIG.6A

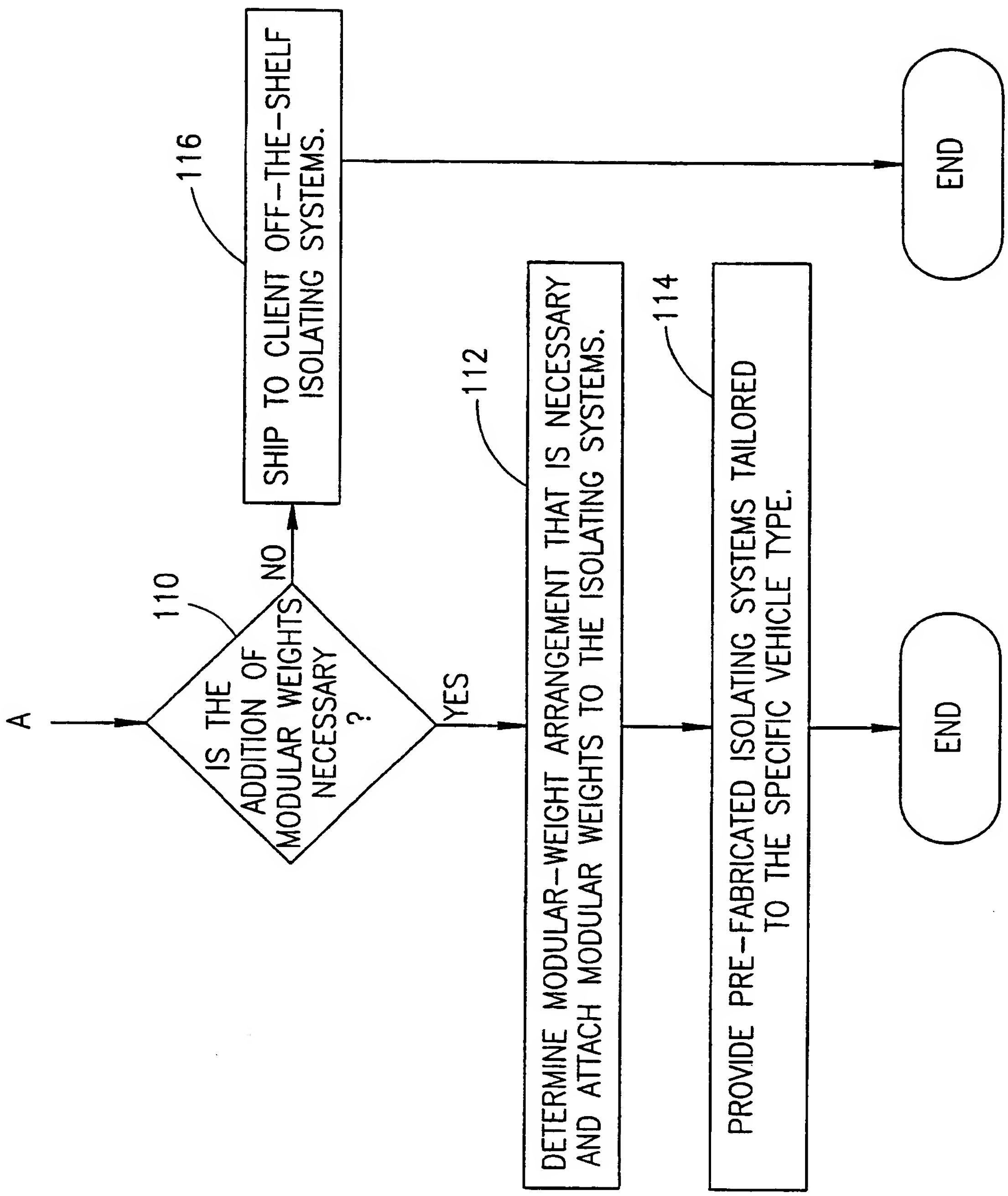
A
IS THE ADDITION OF MODULAR WEIGHTS NECESSARY ?
110
NO
YES
SHIP TO CLIENT OFF-THE-SHELF ISOLATING SYSTEMS.
116
END
DETERMINE MODULAR-WEIGHT ARRANGEMENT THAT IS NECESSARY AND ATTACH MODULAR WEIGHTS TO THE ISOLATING SYSTEMS.
112
PROVIDE PRE-FABRICATED ISOLATING SYSTEMS TAILORED TO THE SPECIFIC VEHICLE TYPE.
114
END

FIG.6B

INTERNATIONAL SEARCH REPORT

Inter. ɔnal Application No
PCT/IL 00/00712

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16F15/08 G11B33/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16F G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	EP 0 780 845 A (HITACHI LTD) 25 June 1997 (1997-06-25) column 7, line 7-21 column 9, line 18-30 column 8, line 38-48; figures	42
A		1-41
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 13, 30 November 1999 (1999-11-30) & JP 11 210817 A (PORIMATEC KK), 3 August 1999 (1999-08-03) abstract	43-52

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 February 2001	05/03/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Pöll, A

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	DE 39 14 303 A (THOMSON BRANDT GMBH) 31 October 1990 (1990-10-31) figures ---	1,43
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A	US 4 713 714 A (GATTI JOHN E ET AL) 15 December 1987 (1987-12-15) figures -----	1

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Information on patent family members

Inter. ›nal Application No

PCT/IL 00/00712

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